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RABBIT MEAT AS FUNCTIONAL FOOD

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Abstract
When choosing food products, the consumer is not only looking at their obvious nutritional function, but is increasingly looking for products that support health or counteract the onset of disease. Functional food is defined as food containing one or more ingredients that are not nutritional and have a selective and positive effect on specific functions of the human body. These are foods and beverages that have a documented beneficial effect on human health beyond that attributable to the presence of nutrients considered as essential. Rabbit meat, thanks to a number of positive properties such as its high content of easily digestible protein, low cholesterol content, low sodium content and favourable fatty acid profile, can be classified as a functional product with a positive effect on the human body.
Keywords: rabbit, functional food, meat

The concept of functional food

The human diet has undergone enormous modification over the centuries. This was mainly due to changes in eating habits, and a change in the biological value of the food available. Unstoppable economic and scientific development has contributed to this (Koziol et al., 2017).

In modern times, the meals consumed are largely highly processed. They are high in saturated fat and simple sugars, while the content of complex carbohydrates and dietary fibre is low (Cieślik et al., 2011). However, growing public awareness of the negative effects of the above-mentioned ingredients on human health is leading to an increasing preference for low-processed products, so-called 'bio' products and organic food. The consumer is looking for innovative products that, in addition to fulfilling the obvious function of covering nutrient requirements, are also intended to meet human health needs. Nowadays, in Asia, and especially in Japan, products with a health-promoting effect account for 15% of the food sold. In the US, cereal products, functional soft drinks and dairy products have the largest share among functional foods. Estimates confirm that almost half of the food in the US is purchased for healthy reasons (Guillocheau et al., 2020). Among functional foods in European countries, dairy products account for almost 50% and cereal products for about 30%. Functional foods are forecast to account for half of the total food market in the near future (Hepburn et al., 2008).

The concept of functional foods originated in Japan. It was recorded as a result of the work of the *Foods For Specified Health Uses* – FOSHU programme in 1991. *Functional food* is defined as food containing one or more ingredients that are not nutrients, but have a selective and positive effect on specific functions of the human body. These are foods and beverages that show documented beneficial effects on human health beyond that due to the presence of nutrients considered as essential (Błaszczyk and Grześkiewicz, 2014).

Characteristics of functional foods

Consensus of the Scientific Concept of Functional Food is a document in which detailed characterisation of functional foods emerged in 1998. This document was the result of the work of the European Commission '*Functional Food Science in Europe*' (FUFOSE), coordinated by the *International Life Science Institute* (ILSI). The aforementioned organisation gives the following definition of functional food: functional food is food that, through its physiological active ingredients, makes it possible to provide health benefits independently of its function, i.e. proper nutrition (Karwowska and Bogacz, 2007). In order to be called functional, food must fulfil a number of properties:

a. It remains conventional food and is part of the daily diet
b. It should have an increased content of the active ingredient, or the addition of an active ingredient not normally found in the food in question
c. It has a scientifically proven beneficial effect on human health
d. It can affect well-being, improve health, or reduce the risk of disease (Błaszczyk and Grześkiewicz, 2014)

Methods of obtaining functional products and their breakdown

Functional foods are also called foods designed to meet specific body needs (designer foods, tailored foods) in some scientific studies. Designer foods can be produced conventionally, or with technology. Conventional production uses raw materials from special livestock and crops grown under specific conditions. Raw materials can be obtained through variety selection or biotechnological modifications, including genetic modification. These measures are aimed not only at introducing new desirable ingredients or increasing their content, but also at eliminating ingredients that may have a negative impact on the human body (Grajeta, 2004).

Technologically modified functional foods are obtained by enriching raw materials with particular bioactive substances or their compositions, by appropriately composing individual formulation ingredients in products, by reducing or using substitutes for undesirable ingredients such as fat, cholesterol, salt or sugar, and by increasing the availability and assimilability of nutrients through the introduction of substances with synergistic effects, and by eliminating anti-nutritional substances (Arai, 1996; Antosiewicz, 1997).

The concept of functional foods is very broad and functional products can therefore be divided in several ways. Based on their composition, functional foods are divided into fortified, low-energy, high-fibre, probiotic, low-sodium, low-cholesterol or energising foods. In terms of purpose, it is divided into foods that reduce the risk of developing cardiovascular disease, reduce the risk of developing cancer, reduce the risk of developing osteoporosis. This can include foods for people under stress, for the elderly, dietary foods for people with metabolic and digestive disorders, for athletes, for pregnant and lactating women, for infants, for adolescents during the intensive growth phase, as well as those affecting mood and psycho-physical performance (Grajeta, 2004). It helps reduce mental illnesses such as depression, dementia and attention deficit hyperactivity disorder (ADHD). It can also prevent the occurrence of rheumatoid arthritis or asthma, thereby improving population health (Riediger et al., 2009).

The beneficial effects of functional foods are mainly due to the presence of bioactive ingredients with health-promoting properties in these foods. The following are considered to be the bioactive substances that make foods functional: dietary fibre, oligosaccharides, certain proteins, lactic fermentation bacteria, antioxidant vitamins, choline, lecithin, phytochemicals such as flavonoids, carotenoids or phytosterols, and n - 3 and n - 6 polyunsaturated fatty acids (Hasler, 1998).

Biological value of rabbit meat

In recent years, there has been a decline in consumer interest in so-called red meat, which has been influenced by greater concern for health, as well as the desire to extend life expectancy. This results in consumers choosing products that are easily digestible, low in calories, low in cholesterol, but also attractive in terms of sensory characteristics such as palatability, juiciness or crispness. These characteristics most closely resemble those of poultry meat, so often chosen by consumers for its high protein content and low fat percentage (Kowalska, 2006). However, events in recent years, such as the outbreak of 'bird flu' H5N1, or the detection of dioxins in chicken muscle, have led to a search for alternative sources of high-quality protein. Rabbit meat is a substitute for poultry and has all the best characteristics of poultry meat, as well as a favourable fatty acid profile and low energy value (Pomianowski et al., 2015).

The main components of meat, with the exception of water, are proteins and fats. Rabbit meat is a lean, easily digestible meat, rich in proteins with a high biological value and characterised by high levels of essential amino acids. Thanks to these characteristics , it is classified as a particularly easily digestible meat, suitable for children, the elderly and allergy sufferers alike (Para et al. 2015).

Of the aforementioned amino acids, lysine, classified as a basic amino acid, has the highest proportion in rabbit meat, as shown in Table 1. In the body, it plays a huge role in the construction of bone and muscle proteins. It is involved in calcium absorption, tissue renewal or antibody formation. It is also responsible for maintaining a normal diurnal rhythm. Among other things, its deficiency can lead to anaemia and hair loss (Arif et al., 2010). Compared to other meats, rabbit meat is richer in lysine, sulphur-containing amino acids, threonine, valine, isoleucine, leucine and phenylalanine (Hernandez and Dalle Zotte, 2010). In addition, rabbit meat contains no uric acid and is low in purines (Dalle Zotte and Szendro, 2011).

Table 1. Level of essential amino acids in the protein of muscle tissue of rabbits (%) (Szkucik and Libelt, 2006)

Amino acid	Muscles			Mean
	Loin	Shoulder	Thigh	
Arginine	6,97	6,64	6,62	6,74
Histidine	3,38	3.46	3,44	3.46
Isoleucine	4,07	4,10	4,06	4,08
Leucine	7,75	7,95	7,88	7,86
Lysine	7,88	7,96	7,94	7,93
Methionine + cystine	5,15	5,23	5,20	5,19
Phenylalanine + tyrosine	9,69	9,70	9,64	9,68
Threonine	5,35	5,31	5,38	5,34
Tryptophan	1.69	1,38	1.63	1,60
Valine	5,15	5,19	5,23	5,20

The fat contained in rabbit meat is mainly composed of saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA), which account for approximately 36.9% and 34.6% of the total fatty acids in rabbit hind limb meat (Table 2). Monounsaturated fatty acids (MUFA) account for approximately 28.5% of all fatty acids. The most common acids are oleic acid (C18: 1), palmitic (C16: 0) and linoleic acid (C18: 2), showing a content of more than 20% of total fatty acids (Hernandez and Gondret, 2006).

Table 2. Fatty acid content in rabbit hind limbs (mg/100 g meat) (Hernandez and Gondret, 2006)

Fatty acids	Mean ± s.e.
Capric acid (C10:0)	3,19 ± 1,01
Lauric acid (C12:0)	6,27±0,68
Myristic acid (C14:0)	67,1±2,82
Palmitic acid (C16:0)	712±24,6
Trans-palmitoleic acid (C16:1 cis ω9)	9.36 ± 0.36
Margaric acid (C17:0)	16.9 ± 0.63
Ginkgolic acid (C17:1)	6.74 ± 0.58
Stearic acid (C18:0)	185 ± 5.88
Oleic acid (C18:1 ω9)	635 ± 24.3
Asclepic acid (C18:1 ω7)	34.9 ± 1.32
Linoleic acid (C18:2 ω6)	777 ± 33.2
Alpha-linolenic acid (C18:3 ω3)	81.2 ± 4.81
Arachidic acid (C20:1)	9.96 ± 0.73
Eicosadienoic acid (C20:2 ω6)	12.8 ± 0.58
Dihomo-γ-linolenic acid (C20:3 ω6)	6.68 ± 0.54
Arachidonic acid (C20:4 ω6)	45.4 ± 1.24

Oleic acid has a hypocholesterolemic effect - it lowers cholesterol and LDL lipoproteins. Numerous studies show that MUFAs provided with food have a protective role in the prevention of atherosclerosis. Among the PUFAs, a distinction is made between linoleic acid C18:2 n-6 and α-linolenic acid C18:3 n-3, as well as compounds belonging to their families: eicosapentaenoic acid (EPA) C20:5 n-3 and docosahexaenoic acid (DHA) C22:6 n-3, which are essential dietary components as the body is unable to synthesise them on its own. The n-3 fatty acids have a therapeutic and preventive effect on cardiovascular disease, counteracting arrhythmias and clot formation, also lowering blood pressure and influencing the functioning of the nervous system. PUFA n-3 are essential for the proper functioning of immune cells and counteract autoimmune diseases such as rheumatism and arthritis (Zymon and Strzetelski, 2010).

The amount of linoleic acid is about ten times higher in rabbit meat than in beef and lamb meat and about twice the amount recorded for pork meat. The linolenic acid content, which is 3%, is also exceptionally high, compared to those recorded in other meats: 1.37% in lamb, 0.70% in beef and 0.95% in pork. However, rabbit meat is characterised by low amounts of EPA and DHA (Hernandez and Gondret, 2006).

The fatty acid profile of rabbit meat is influenced by several factors such as breed, sex, tissue type, age, and the value of the animal's body weight on the day of slaughter. The composition of the dietary ration also has an important influence. It is through nutrition that the fatty acid profile of the rabbit meat obtained can be subjectively improved quickly and effectively (Cobos et al., 1995). A study carried out by Dal Bosco et al. in 2004 on the use of a-linolenic acid and vitamin E in rabbit nutrition proved that the addition of these substances in the feed significantly increases the unsaturated fatty acid content of rabbit meat and at the same time reduces the level of saturated acids. Among other things, the proportion of a-linolenic acids, EPA and DHA increased significantly. Also Kowalska in 2008 attempted to modify the fatty acid profile by using a nutritional additive that was a mixture of rapeseed oil and fish oil. The use of oils had a positive effect on the fatty acid composition of the meat. There was a decrease in total saturated fatty acids and an increase in polyunsaturated fatty acids, especially EPA and DHA. Equally interesting is the 2008 experience of Tres et al. who compared the effect of an oil rich in n-3 acids, which was flaxseed oil, with an oil rich in n-6 acids, in this case sunflower oil. The experiment carried out proved that sunflower oil increases the content of n-6-bonded acids in rabbit meat. Among other things, significant differences were noted in linoleic acid levels. It was also noted that n-3 acids were significantly higher in meat from animals supplemented with linseed oil.

Interest in conjugated linoleic acid (CLA) has increased in recent years due to its potential health benefits for humans. Studies on several animal models of the cis-9, trans-11 isomer of CLA have shown that it may have anti-cancer properties. However, it has not been officially confirmed that this naturally occurring isomer in meat has health effects on cancer prevention. Other beneficial biological characteristics attributed to CLA (both cis-9, trans-11 CLA and trans-10, cis-12 CLA) include antioxidant, antiatherosclerotic and anti-diabetic properties, immune system protection and are involved in bone formation (Zhang et al., 2010). Monogastric animals are unable to synthesise CLA and it must be supplied with food, but rabbits, thanks to their coprophagy, are able to deposit CLA in their muscles (Corino et al., 2007). The concentration of CLA in rabbit meat can be increased by supplementation with synthetic CLA. This was demonstrated by an experiment carried out by Corino et al. in 2007. New Zealand White rabbits were fed a feed containing 0.5% added CLA. The content of fat and CLA isomers in the longissimus dorsi muscle was statistically higher in rabbits fed the experimental feed than in those in the control group. The fatty acid composition of the longissimus dorsi muscle was modified and the oxidative stability of the fatty acids was increased. The addition of CLA increased plasma triglyceride, cholesterol and glucose levels.

One of the representatives of the lipid group is cholesterol a steroid-derived compound infamous for the cardiovascular diseases it causes when present in the blood in too high a quantity. The problem of cardiovascular disease mainly affects countries with a high consumption of pork, and hypercholesterolaemia is blamed on saturated fatty acids, which promote the accumulation of the 'bad fraction' of cholesterol in the blood. However, a small amount of dietary cholesterol is essential, as it is an important substrate in the synthesis of sex hormones, corticosteroids, or bile acids. As can be seen from Table 3 shown, rabbit meat has an exceptionally low cholesterol content of 35 - 50 mg per 100 g of meat. This is twice as low as in poultry meat, considered a dietary product (Kowalska, 2006).

Like other 'white' meats, rabbit meat contains a low percentage of iron, as shown in Table 4. It is also low in sodium, one of the main causes of cardiovascular diseases such as hypertension. This makes it an ideal meat for people at risk of the disease (Lombardi-Boccia et al., 2005).

Selenium is an important micronutrient due to its role in the regulation of many physiological functions in the body. As an integral part of selenoproteins, among other things, it controls the function of the antioxidant system. The daily selenium intake is 70 and 55 μg for men and women respectively. The level of selenium in rabbit meat varies depending on the type of feed intake the animal receives. In animals consuming feed not supplemented with selenium, values of 9.3 to 15.0 μg/100g of meat are recorded, and in rabbits fed feed supplemented with 0.50 mg selenised yeast/kg of feed around 39.5 μg/100g of meat. Considering the daily human requirement for selenium, just 140 g of selenium-fed rabbit meat would cover the recommended daily intake of an adult. If meat came from rabbits that did not receive supplementation, the daily selenium intake would be covered by approximately 500 g of rabbit meat (Dalle Zotte and Szendro, 2011).

Just as important as minerals for the proper functioning of the body are vitamins. Their consumption ensures an improved external appearance, improves the quality of hair, skin and nails, boosts immunity, promotes the absorption of minerals into the body, or ensures proper fat burning. There is a constant search for foods that are a source of as many vitamins as possible. Rabbit meat is a great source of B vitamins and their content is illustrated in Table 5. Consumption of 100 g of meat meets the need for 8% vitamin B2, 12% vitamin B5, 21% vitamin B6 and 77% vitamin B7. It also provides the daily requirement for vitamin B12 (Hernandez and Dalle Zotte, 2010).

Table 3. Cholesterol content in various food products (Kowalska, 2006)

Type of product	Cholesterol content [mg] in 100 g of product
Hen's eggs (yolk)	650–750
Pork fat	110–145
Chicken meat	78–98
Veal	40–50
Beef	45–60
Rabbit meat	35–50
Poultry fat	72–76
Rabbit fat	35–38

Table 4. Mineral content in meats of various animal species (mg/100 g) (Dalle Zotte, 2004)

Mineral	Pork	Beef	Veal	Poultry	Rabbit
Ca	7–8	10–11	9–14	11–19	2,7–9,3
P	158–223	168–175	170–214	180–200	222–234
K	300–370	330–360	260–360	260–330	428–431
At	59–76	51–89	83–89	60–89	37–47
Fe	1,4–1,7	1,8–2,3	0,8–2,3	0,6–2,0	1,1–1,3
Se, µg	8,7	17	<10	14,8	9,3–15

Table 5. Vitamin content in rabbit meat (Combes, 2004)

Vitamins	Mean content in 100 g meat
A (Retinol) µg	Trace
E (Tocopherol) mg	0,186
B_1 (Thiamine) mg	0,082
B_2 (Riboflavin) mg	0,125
B_3 (Niacin) mg	9,6
B_5 (Pantothenic acid) mg	0,6
B_6 (Pyridoxine) mg	0,34
B_8 (Biotin) µg	0,7
B_9 (Folic acid) µg	5
B_{12} (Cobalamin) µg	6,85

Like other meats, rabbit meat contains only trace amounts of vitamin A, which, however, can be found in greater quantities in rabbit liver. Additional vitamin E supplementation in the diet (200 mg/kg feed) leads to a 50% increase in the vitamin E content of rabbit meat (Hernandez and Gondret, 2006).

As can be seen from the literature review above, rabbit meat is a product that, in addition to its primary nutritional function, has a number of ingredients and properties that could give it the title of functional food. Research is constantly being conducted to improve its quality and chemical composition, with the result that rabbit meat may soon become a culinary raw material that can easily replace the much-used pork or poultry.

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SUMMARY

When choosing food products, the consumer not only pays attention to their obvious nutritional function, but more and more often looks for products supporting health or preventing the occurrence of diseases. Functional food is defined as a food that contains one or more non-nutrients, the action of which produces a selective and positive effect in relation to specific functions of the human body. These are food and drink products that have a documented, beneficial effect on human health over and above that resulting from the presence of essential nutrients in them. Rabbit meat, thanks to a number of positive properties, such as high content of easily digestible protein, low cholesterol, low sodium content, or favourable fatty acid profile can be included in the group of functional products that have a positive effect on the human body.

Keywords: rabbit, functional food, meat